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PHYS265

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Lab 1: The Apollo Mission Report

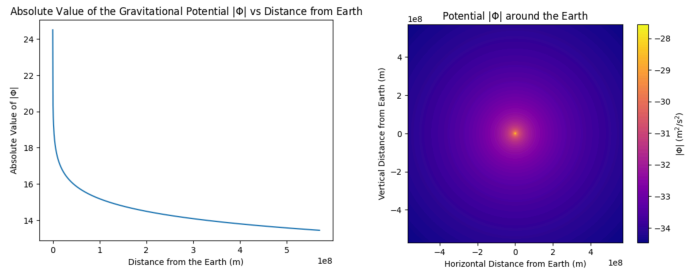
I. Introduction

As we know it, the space race is still in its fundamental years, with countries like the Union of Soviet Socialist Republics (USSR) and other first-world countries trying to establish their lead in space research and development capabilities. This means it's essential for NASA to stay in the race to establish itself in the industry. As a result, I've designed a report on our research for funding purposes to understand the gravitational potential and forces that the mission will experience and our predictions of the rocket performance while carrying Saturn V.

II. The Gravitational Potential of the Earth-Moon System

The potential at a distance *r* from a mass *M* is given by $\Phi(r) = -\frac{GM}{r}$, where G is the gravitational constant. We defined a function that calculates the distance between two coordinates, and returns the value of the potential at that distance while checking for singularities using numpy.isclose(). We assumed that the Earth was the origin, and calculated the potential at distances from (0,0) and plotted them as the absolute value of the potential as a function of distance and a color-mesh plot of the potential values (Figure 1).

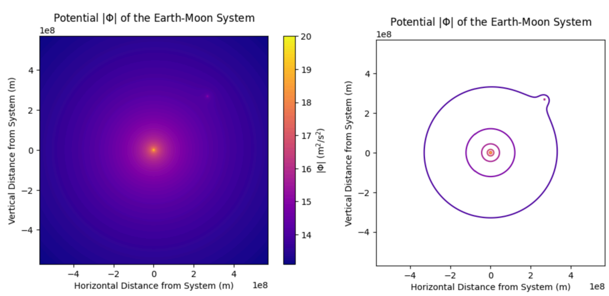
Figure 1.



Note. Left: 1D plot of the absolute value of the potential as a function of distance *x*. Right: 2D color-mesh plot of the potential at various distances from the Earth.

Next, we calculated the way this data would be affected by accounting for the Moon's effect on the system's gravitational potential by adding up the individual potentials at a distance from the system and plotted an updated color-mesh and contour plot (Figure 2).

Figure 2.



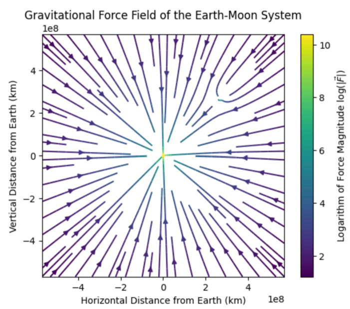
Note. Left: 2D color-mesh plot of the gravitational potentials in the Earth-Moon system. Right: 2D contour plot of the gravitational potentials in the Earth-Moon system.

III. The Gravitational Force of the Earth-Moon System

We then analyzed the gravitational force of the Earth-Moon system by plotting a 2D streamplot of the gravitational force the system will exert on the Apollo 11 command module (Figure 3). This was done by creating a function that calculates the gravitational force $\overline{F_{21}} = -G\frac{M_1 m_2}{|\overline{r_{21}}|^2}\widehat{r_{21}}$ where the r vector is the displacement vector from M_1 to m_2 and returning the

F_x and F_y values, accounting for singularities using the numpy.isclose() method and approximating the Earth as a singular point.

Figure 3.



IV. Projected Performance of the Saturn V Stage 1

We also projected the performance of the rocket in Stage 1 by calculating the burn time using $T = \frac{m_0 - m_f}{m}$ where m_0 is the wet mass of S-1C, m_f is the dry mass of S-1C, and m is the burn rate of S-1C, resulting in a value of 157.69 kg/s. We calculated the altitude of the rocket by calculating $h = \int_0^T \Delta v(t)dt$, where v(t) is Tsiolkovsky's equation, $\Delta v(t) = v_e ln(\frac{m_0}{m(t)}) - gt$ (v_e is the fuel exhaust velocity, g is the gravitational acceleration, t is time, and $m(t) = m_0 - mt$), using scipy.integrate.quad() and estimated the altitude to be 74093.98 m.

V. Discussion and Future Work

This report explains the current understanding of gravitational forces and potentials the Apollo spacecraft will encounter. It's important to note that several assumptions were made including neglecting drag force, which resulted in the altitude we calculated (74.094 km) being an overestimate of the actual altitude value despite the burn times being approximately the same. Future work should aim to minimize assumptions made by incorporating air resistance and drag force into the calculations and could reconsider the potentials for the Earth-Moon system considering they aren't a singular point.